Vol. VIII. JANUARY, 1892. No. 1.

JOURNAL

OF THE

New-York Microscopical Society

EDITED BY

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WAVERLEY AVE., FLATBUSH, L. I., N. Y.

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New York:

PUBLISHED FOR THE SOCIETY,

QUARTERLY.

PRESS OF STETTINER, LAMBERT & CO.,
22, 24 & 26 READE STREET.
1892.

[Entered at the Post-Office at New York as second-class matter.]

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JOURNAL

—OF THE—

NEW-YORK MICROSCOPICAL SOCIETY

CONTAINING ITS TRANSACTIONS AND PROCEEDINGS.

PUBLISHED QUARTERLY.

All communications for the JOURNAL, all subscriptions, and all exchanges, should be addressed to the editor, REV. J. L. ZABRISKIE, Waverley Avenue, Flatbush, L. I., N. Y.

Terms of Subscription:—In the United States and Canada, One Dollar per annum, beginning with the January number. In Great Britain and Europe, Five Shillings per annum.

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WHAT IS A DIATOM?

A LECTURE

BY CHARLES F. COX.

(*Delivered December 18th*, 1891.)

A few years ago, one of the newspapers of this city poured forth most biting sarcasm upon the presumably impractical and altogether useless system of education pursued at the College of the City of New York, because upon its annual examination papers there had appeared the question which I have adopted as the title of this lecture.

Although it is not at all likely that my words will ever reach the editor who put forth this ignorant plea for a shallow utilitarianism, I have felt, ever since I read his peppery article, that I should like to harp upon the theme for which he expressed his bitter disdain. Not because the summit of wisdom is attained when one knows what a diatom is, but because I believe that even yet some good may be done by insisting upon the value there is in pure science. The editor with whom I thus take issue, if he ever was a college student, probably acquired his "education" in the days when there was no place in the curriculum for any science that went below the glittering surface of knowledge. But there has been a great change in recent years. Not only is science more *taught*, but *more science* is taught; and, along with the

improvement that has taken place in educational methods, has come an increased appreciation of the unconvertible products of learning,—those intellectual residua which no one expects to turn into bread and butter. The world is finding out that truth, like virtue, is its own reward. But, since knowledge is spreading with tremendous rapidity, and no man can hope to cultivate the whole length and breadth of even one department, he who would be truly learned must dig deep at a single point. It is an old saying, I believe : "Not he who knows many things, but he who knows much, is the wise man."

Now, I fully appreciate the fact that a knowledge of the habits, structure, and systematic position of the diatoms is not a *necessary* part of any man's intellectual equipment. Even scientific specialists, whose field of work includes this class of objects, manage to get along very well with hardly more than superficial information as to their appearances and characteristics, while men who pursue the study of these minute wonders with more than ordinary persistency and enthusiasm have come to be known by the half-contemptuous title, *diatomaniacs*. I am not particularly anxious to inoculate new victims with their mania, but I shall be glad if, under cover of a presentation of a few of the questions which engage their attention, I am able to promote interest in the general subject of microscopical research. I believe it will be found that a study of this one family of very lowly beings will bring before us most of the leading problems of biology, and perhaps some of those of physics, besides ; and I shall be disappointed if, around the nucleus which my subject supplies, I fail to gather a body of fact and speculation the contemplation of which will prove both entertaining and stimulating.

I think there is no material attribute of which science justly takes as little account as it does of mere size. All immeasurable things seem great, whether they are immeasurably large or immeasurably small ; and in the same way all inscrutable phenomena are awe-inspiring and overpowering. Whether we look upwards and outwards, through the telescope, at the numberless revolving orbs of the universe, or downwards and inwards, through the microscope, at the myriad active plastides of an organized creature, the same or similar questions ultimately present themselves for solution, without regard to the prodigious size and

almost infinite sweep of the one class of objects, and the infinitesimal dimensions and limited range of the other. Of what significance are such magnitudes and distances as we can apply our rules to, when neither the telescope nor the microscope has penetrated to a final boundary? The fact is, we are overwhelmed by the futility of our effort to follow out in imagination an endless series, whether we look in one direction or turn about and look in the other.

The familiar identification of "the law which moulds a tear" and that which "guides the planets in their course," may be paralleled in very various similitudes throughout nature, and the fact that an object of investigation is minute in size, or comparatively simple in structure, does not necessarily render the primal causes of its being and actions any more easily discernible than they are in the case of that which is grand and complicated. On the contrary, complexity and multiplicity of parts have a tendency to appear self-explanatory. Thus our own highly developed body, with its numerous correlated and co-ordinated organs, is regarded as less mysterious than is the apparently undifferentiated and organless rhizopod, a seeming amorphous sample of the so-called basal "life-stuff." So, too, the giant steam engine, which impresses us mostly by its nearly irresistible power, never appears as wholly inexplicable in its operation as does the simple living current of protoplasm circling in a microscopic cell of Chara or Anacharis. In reality, the vaster and more complex a mechanism is, the more points it presents at which we are able to see the immediate connection of cause and effect, and in following back from one of these points to another we fancy we are explaining the whole *modus operandi*. We realize the essential mysteriousness of the matter only when we reach an effect without an obvious cause, as we are sure to do if we pursue the subject persistently and deeply enough.

Thus all thorough study and research end, as they begin, with a question. The interrogation-mark is, after all, the symbol of the highest and latest human wisdom. My lecture, therefore, if it pushes deep enough, is likely to close, as it opens, with the inquiry: *What is a Diatom?*

Meanwhile, however, we may perhaps move our knowledge a link or two along the chain of queries which constitutes the sci-

ence of the subject, even if we are unable to solve our problem in its entirety. By way of accomplishing what we can in this direction, it is necessary to begin by procuring specimens of the things we propose to investigate. Fortunately they are not difficult to obtain. In fact, they are amongst the most plentiful of all objects, though not ordinarily within the range of our unaided sight. To him who has access to running brooks, quiet ponds, or the greater lakes, a range of several hundred species or varieties is open. To the explorer of brackish estuaries and the deep salt sea, other hundreds offer themselves. To the one who can dig into the extensive deposits of their fossil remains, still other hundreds present their interesting forms. But even to us who dwell within the barren walls of a great city an unstinted supply of certain kinds is always close at hand, for the simplest of filters applied to a Croton-water faucet will, in a few minutes, furnish at least a half a dozen species; and this will be our most convenient source of supply.

If we take the product of our rude filter and place dippings from it under the microscope, we shall at first experience some embarrassment because of the multiplicity of objects presented to our view. There will be an abundance of sand and other amorphous and inorganic substances, and amongst these are likely to be scattered fragments of leaves and stems of exogenous plants, bits of linen, cotton or woollen threads, and various other articles of extraneous origin. Prominent, however, because of their bright color and considerable size, will appear the long jointed tubes of a few of the thread-like aquatic weeds, while deep down through the film of water we shall discern two similar and yet somewhat different sorts of diminutive bodies, which are sure to fasten our attention by their very pretty and symmetrical forms. The one kind is of a deep green color, the other of a thin reddish or brownish-olive hue ; and both will exhibit some differencing of their internal substance into denser and more attenuated parts, with here and there open, oily-looking spots. The dark green bodies appear as single capsules, narrowed, if not pointed, at each end, and floating free or else as loose aggregations of similar flattened cells, forming either rosettes or lace-like mats of various patterns. The brownish bodies will be found either as narrow rods, laid side by side in long bands, or joined

to one another by their corners so as to form zigzag lines, or else as disconnected individuals with a very striking resemblance in shape to miniature skiffs or boats. If we make use of some other source of supply than our Croton-water faucet, we may obtain a much greater variety of forms in both the classes of objects referred to, though we shall not fail to notice a certain parallelism in the morphology of the two families, which may easily cause us to think them but one. They are, however, quite distinct, as we shall see. Those forms which I have spoken of in this particular case as decidedly green in color (although this is not a decisive characteristic throughout the family) are known as *Desmids*. Those which I have described as being of a brownish hue are *Diatoms*.

But now, if we look more closely at our desmids and diatoms, we shall discover that the latter have a very rigid, hard, and almost indestructible carapace or shell, while that of the former is hardly more than a stiffened membrane which is with difficulty discerned at all. In the diatoms the enclosing case will prove to be a solid deposit of nearly pure silica; but in the desmids it will be found to be a semi-flexible film slightly infiltrated with carbonate of lime. This is an important distinction, which forms the basis for a sharp separation of the two groups of forms. As regards the particular specimens we are supposed to have under immediate inspection, however, we shall by this time have observed a difference which to most minds will constitute a clearer demarcation than could be established by any other criterion; and that is that our desmids are apparently quite passive, while the little boat-shaped diatoms actively glide about with a seemingly well-defined purpose.

You will need to abstain from generalizing too far and too fast in this connection, for all diatoms do not possess this power of locomotion, since not only are some of them united to one another, as we have seen, but many sorts are attached to plants and other fixed objects, although the theory has been advanced that all diatoms are, at one time or another, free and migratory. On the other hand, while desmids are never permanently anchored, locomotion is not a prominent characteristic of even the solitary forms, because, while it is pretty general throughout the group, it is too slow to attract attention, and, when observed, has not that

appearance of voluntariness which is exceedingly striking in the movements of the free, boat-shaped diatoms. When you have a specimen of the latter under your microscopically-aided eye, you will see it slide over the bottom of your artificial pond without discernible machinery but with very appreciable force and considerable speed. If it meets an obstruction which is not too large, it pushes it aside, but, if too heavy, it halts a few seconds and then reverses its invisible engine and changes its course.

Upon seeing this operation for the first time, one inevitably jumps to the conclusion that he is witnessing the exercise of what, in the highest orders of creatures, we call volition. But again we need to restrain ourselves. Already this microscopic vessel,—perhaps not more than the two-hundredth of an inch long,—has brought us a freight of problems as big as the world! What *is* this diatom? Is it really a living thing? What is the criterion of vitality,—what is life? If the diatom is an organism, to which kingdom of animate beings does it belong? And is there a fundamental and absolute difference between animals and vegetables, and, if so, what is it? When we have disposed of these weighty questions it will be time enough to approach that other great mystery,—the physical basis of mind,—as Alfred Binet has attempted to do in his essay on "The Psychic Life of Micro-Organisms."

Of all the struggles through which scientific progress has been accomplished, none is more interesting than the never-ending conflict of opinion which has raged around the definition of life. There is nothing about which ignorant and thoughtless people are more certain than about their ability to distinguish between that which is alive and that which is dead. On the other hand, amongst the learned and the wise this is one of the unsettled matters which as yet hold out no promise of being set at rest. To the uninformed self-motion is the conclusive evidence of vitality;—that is to say, motion not having an evident cause external to the body moved. "It moves of itself, therefore it is alive," is the offhand expression of the popular judgment.

But if visible motion ever furnishes a trustworthy test, it is under very strict conditions and in a very limited domain. That it supplies no line of demarcation between the organic and the inorganic worlds was made known in 1826 by Robert Brown's

discovery of the ceaseless activity, under favorable circumstances, of probably all small particles having a diameter of less than the one-five-thousandth of an inch. This phenomenon, which has come to be known as "the Brownian movement," but the cause of which has never been determined, might easily deceive the inexperienced observer into thinking he had under the microscope a lively colony of animalcules when, in fact, he might be looking at almost any finely-divided insoluble substance,—even, perhaps, at iron filings. In 1874 I rubbed up in water a little gamboge, which I confined in a hermetically-sealed cell, and which, for more than fourteen years (as long as the cell remained intact), was brought out periodically to illustrate the fact that "things are not what they seem." Numerous other illustrations of this uncertainty of appearances might be drawn from things in sight and above sight, as well as beneath sight; and it is well to remember in this connection that, broadly considered, motion is an attribute of every form and condition of matter, great or small, simple or combined, inorganic or organized.

All forces are now regarded as modes of motion, and, since the abandonment, some fifty years ago, of the theory of a vital essence or principle,—which had itself superseded an earlier doctrine of a vital entity or substance,—science has become accustomed to correlating the vital forces with the physical and the chemical, and to looking upon all phenomena as different manifestations of a common activity, varying only in intensity and range.

This is, after all, merely a return to a method which has prevailed at often-recurring periods,—the method of reducing all scientific facts to a common denominator. No phase of philosophical thought is more persistent than this tendency to find a fundamental unity underlying all diversity,—to clear away perplexing mysteries by diffusing them through a universal solvent. Thus biology has had to pass several times through a period in which the best intellects and the most serious workers were devoted to a search for an elixir of life,—something which should embody the principle of creative power. These endeavors, however, like the efforts of the alchemists of old, have always ended in philosophical abstractions rather than in a concrete result upon which science can lay its material hand.

This proved to be the case with the notion which Coleridge worked out in his "Theory of Life,"—a vein which many philosophizers had followed before his time and one which some occasionally dig at even now. The idea they seek to develop is that which Herbert Spencer himself expressed in one of his early essays, when he said: "The characteristic which, manifested in a high degree, we call Life, is a characteristic manifested only in a lower degree by so-called inanimate objects."

But this conception was too indefinitely homogeneous to rest quietly in Mr. Spencer's mind. We all know how it subsequently evolved into the famous definition, given in his "Principles of Biology," namely, that life is "the definite combination of heterogeneous changes, both simultaneous and successive, in correspondence with external co-existences and sequences." This idea is very different from the ideas which were previously entertained and which various authors had attempted to record in brief sentences and even single words. Bichat's definition of life was: "the sum of the functions which resist death." De Blainville's was: "the twofold internal movement of composition and decomposition at once general and continuous." Lewes's was: "a series of definite and successive changes, both of structure and composition, which take place within an individual without destroying its identity." All of these definitions are open to serious objection, as has been shown very clearly by Dr. Drysdale in his inaugural address as President of the Liverpool Biological Society. He himself proposes, as being most closely in accordance with the latest development of the protoplasmic theory, the definition of life as "the consumption and regeneration of protoplasm in co-operation with external conditions, pabulum and stimuli," which, however, he thinks may be further simplified as follows: "Life is the interaction of protoplasm with the environment."

Now, all definitions are true only from fixed points of observation. They vary both in time and in space,—that is, as we pass from the knowledge of one period to that of another period, or as we pass from the domain of one sort of learning to the domain of another. Thus, while Dr. Drysdale's definition of life seems to suit pretty well the present knowledge of a worker in the microscopical realm, I can see that it may be very unsatisfactory to the biologist in a broader field and that it may be totally inadequate

to the wants of the investigator of the future, whether in one field or another. For our present purposes, however, it may be good enough, and if we apply the test which it furnishes to our little diatom, we shall find that we have under consideration a really living thing.

This conclusion of course assumes that the diatom possesses, in addition to the hard framework or shell, of which I have already spoken, a body of plastic substance called protoplasm. This, upon close examination, we easily learn to be the case. Very simple methods of investigation show that every frustule (as each individual cell is called) is in reality a glass box enclosing a semi-fluid, nearly transparent, but somewhat granular material, containing, besides the oily-looking spots or vacuoles to which I have before referred, more or less of a yellowish or brownish-green substance, which gives its general color to the whole organism. There is reason to believe that the semi-fluid material also forms an enveloping layer on the outside of the siliceous carapace of all diatoms, and in many instances a similar glycerin-like matter permanently encloses a whole colony of otherwise separate frustules, which passively spend their existence within its restraining grasp. Now, chemical tests disclose the fact that the colloidal mass within the transparent valves is composed of carbon, oxygen, hydrogen, and nitrogen in proportions and relations which characterize an organic substance, and a great number of converging facts, derived from long-continued observation, go to prove that this substance is the seat of all the changes, chemical and physical, which constitute what Dr. Drysdale calls the "interaction of protoplasm with the environment." In other words, it is the consumption and regeneration of this substance "in co-operation with external conditions, pabulum and stimuli," which make up the sum of phenomena embraced in this humble creature's life-history. We therefore conclude that this substance is protoplasm.

It is through and by this protoplasm that the diatom responds to the influences of heat and light, that it receives and assimilates its food, that it moves from place to place as we have seen the boat-like specimen in the Croton water doing, that it grows and reproduces its kind. It was because of its agency in these matters that Prof. Huxley called protoplasm "the physical basis of life," though its name really means "primary formative

matter," and Beale's designation of it, bioplasm, more definitely expresses the idea of its being a *life* plasma.

But the fact that the living portion of the diatom consists in the main of protoplasm, is not enough to enable us to answer the question whether the diatom is an animal or a vegetable, since protoplasm is common to both kingdoms of the organic world and enters into the composition of all animate things, high and low. Not only is it apparently the essential part of the desmid, the diatom, the amœba, and the rest of the protophyta and the protozoa (the so-called "lowest" living creatures), but it appears to be the seat of all vital action in the water-weed and the fish that swims beside it, the shrub and the reptile that crawls at its root, the tree and the quadruped that enjoys its shelter,—even in man himself, who excels all and rules all. In Nitella, Valisneria, or Anacharis you may see the colorless current circling in every cell, building and unbuilding with a chemistry beyond our ken, and in all the higher animals it seems to be the matrix in which are fashioned the tissues and the bones, the source also of the contractility of the muscles and the sensibility of the nerves. In your own warm blood you will find protoplasm, in the form of the "white corpuscles" which creep and crawl with an activity and independence quite mystifying to the observer, but doubtless with a useful and important purpose, if we only knew what it was; and if you could look into your own wondrous brain you would probably find protoplasm in some way underlying all consciousness and thought.

But when I thus talk of protoplasm, I use the word as a generic term, in the same manner as I should speak of tissue or muscle. There is a difference between the ideal, or philosophical, protoplasm, and the real, or physiological, protoplasm. The philosophers have created for themselves, by an *a priori* process, a substance which is absolutely homogeneous and structureless, and which is identical in composition and attributes throughout the whole realm of animate nature. On this hypothetical basis they have undertaken to erect a monistic system in which animals and plants actually arise from the same root-stock and are really quickened by the same vital stream. I have no preconceived dislike to such a theory, if it can be proved true; but, unfortunately, the inductive methods of physiology do not confirm this deductive con-

clusion of philosophy. The reason of course is that philosophy has assumed false premises. There is in fact no one protoplasm ascertained to be common to all living things. The latest science proves conclusively that what Huxley laid stress upon as the physical basis of life, and Beale staked his theory of "vital power" upon, as the true "germinal matter," are not structureless colloids, alike wherever found, but that they are complex in structure and various in chemical composition,—in short, that there are probably as many different protoplasms as there are organisms.

How, then, are we to tell whether our diatom is animal or vegetable? Here is another of those points at which ignorance has been accustomed to think itself wise, but where wisdom has come to admit itself ignorant. Prof. Huxley set forth the situation of this matter most admirably in his lecture entitled "The Border Territory between the Animal and the Vegetable Kingdoms," and there has been no essential change in the case since he therein stated it. Naturalists had been in the habit, from the days of Cuvier, of relying upon four proofs which they considered conclusive of the animal nature of any organism. These were (1) the possession of an alimentary cavity, (2) the presence of muscles for locomotion and of nerves for sensibility, (3) the existence of nitrogen as a constituent element of the body-substance, and (4) the exercise of the function of respiration,—the absorption of oxygen and the exhalation of carbonic acid. But all of these distinctions have been shown to be subject to so many exceptions as to destroy their value as tests. For example, the reproductive bodies set free by certain algæ, which, from their resemblance to animals, have been given the name *zoöspores*, are as active in their movements as any animalcules, and to all appearances exercise quite as much volition. They also appear to search for food and are provided with internal spaces which Ehrenberg, not altogether unreasonably, took to be stomachs, and upon the existence of which he founded his family of the *polygastrica*, a division of the animal kingdom in which he included, with numerous zoöspores, not only true animalcules but also all diatoms. It is not yet certain that zoöspores are really destitute of a digestive system, and, as to muscles and nerves, they are certainly as well endowed as are the lowest known animals. On the other hand, many para-

sitical animals, and the males of most rotifers, or wheel animalcules (which occupy a comparatively high position in the scale of organization), have no digestive apparatus whatever, as far as can be discovered, while the fresh-water hydras and many other lowly animal forms receive their food as well at one point as at another, and in fact perform the act of digestion throughout the whole body. So Cuvier's and Ehrenberg's principal criteria of animality have broken down and disappeared from the domain of biology, and along with them have gone all the other old-time tests. Darwin's researches on insectivorous plants gave a fatal blow to the theories built upon sensitiveness and response to stimuli, on the power of complex motion directed to a definite end, and on the appropriation and assimilation of organic food.

For a long time the existence of chlorophyll in an organism was deemed conclusive evidence of its vegetable nature, for chlorophyll is what gives the green color to all the higher kinds of plants, and chemistry had shown that chlorophyll was the seat of those operations which separated the carbon from carbonic acid and built it into the woody substance of the plant, and carbon was regarded as belonging strictly to the vegetable world. But, alas for consistency, it was found that some plants do not contain chlorophyll, and, still worse, that there are certain undoubted animals which are possessed of it and that in their economy it performs the very same duty that it performs in plants.

I would not have it understood from all this that there is a border country into which organisms may wander from the animal and the vegetable kingdoms and therein lose all definite character and all trace of their origin; or that, by crossing this no-man's land, the former inhabitants of one domain may become thoroughly naturalized in the other. There is no such magic about this curious region. Its perplexities and uncertainties mainly grow out of the fact that it is the place where the frayed-out edges of the two kingdoms come together to form a hazy mixture of intermingled fringes. The ravelled threads have not necessarily lost their identity, though we are unable to disentangle them. While there are many living forms which at present cannot be definitely classed with either animals or vegetables, experience leads us to think that, in most cases, if we could trace out the complete life-histories of the doubtful organisms occupying this

middle ground, we should find their lines of relationship leading pretty clearly in one or the other direction. At any rate we should learn that what had an animal origin continues as animal and ends as animal ; that what began as vegetable remains vegetable to the last ;—both completing sooner or later a circle of existence limited by a law of inheritance of which we have not as yet found the secret.

The difficulty with this matter, as well as with the subject of vitality, is that we look for single distinguishing signs when we ought to take into consideration a whole series of phenomena at once. Thus life would prove to be not an entity, an essence, or even a principle, but rather *a process*. In like manner, the criterion of animal life, as distinguished from vegetable, would not be found in assimilation, sensation, self-motion, or any other one thing, but in a group of actions and attributes, by their sum-total turning the scale to the animal side.

In his interesting discussion of this topic, Prof. Huxley reaches the conclusion, now generally accepted, that the nearest approach to a definite dividing line is in the fact that the plant can make the peculiar nitrogenous substance called protein, while the animal must get it from the vegetable realm. "Thus," he says, "the plant is the ideal *prolétaire* of the living world, the worker who produces ; the animal, the ideal aristocrat, who mostly occupies himself in consuming."

But even the distinction here attempted needs to be fortified by other considerations when we come to particular instances, since Darwin has shown that certain of the higher plants eat, as well as manufacture, protein, and the same fact has been demonstrated as to fungi and many other thallophytes. There is, however, no reason to suppose that diatoms are eaters, although the wanderings of the free forms have every appearance of being directed in search of food. But to the best of our knowledge and belief their quest is for inorganic pabulum, if, indeed, it has direct relation to food at all and is not, after all, merely one of those curious modes of dispersion with which we are familiar amongst spores and seeds. As far as we know, the diatom protoplasm has no proclivity for cannibalism, as all animal protoplasms seem to have. Taking this negative quality for what it is worth, and adding it to the general sum of the diatom's other characteristics which com-

mon sense somehow recognizes as belonging to the vegetable kingdom, we arrive at a decision that the object of our consideration is a plant and not an animal.

This may not be a strictly scientific way of settling the question, but how else are we to dispose of it when so great a stickler for inductive methods, as Prof. Huxley, declares that the latest information on this subject tends to the conclusion "that the difference between animal and plant is one of degree, rather than of kind; and that the problem whether, in a given case, an organism is an animal or a plant, may be essentially insoluble"?

Having made up our minds that diatoms lie within the boundaries of the vegetable kingdom, we shall have no difficulty in referring them to that sub-kingdom which includes all non-vascular, or, in other words, leafless and rootless plants,—called *thallophyta*. In this sub-kingdom is the well-known class *Algæ*, which embraces all aquatic thallophytes, and to which therefore the diatoms must belong. Indeed, they constitute a very important sub-class of algæ, which derives its name from them,—the *diatomaceæ*.

The diatomaceæ themselves get their name from the Greek word *διατομος*, which means *cut through*, *cut in two*, or *cut up*, and which was applied to them with reference to the bead-like manner in which the individuals of many genera cling together in fragile strings. These are the forms which earliest attracted attention, and which in common language were described as "brittle-worts," an appellation intended to connote the same characteristic as is denoted by the Greek name. The latter possesses additional appropriateness because of the fact that each frustule is bivalvular in structure, and from the still further fact that one of its modes of reproduction is a cutting in two of every parent cell to form twin descendants. When this process continues through several generations without an actual separation, the result is a loosely united filament, fillet, or flabel, according to whether the parent form was round, square, or wedge-shaped. The string, band, or fan thus produced will be *cut into* at regular intervals and may easily be *cut up*, or broken up, by the application of any external force.

Reproduction by self-division is not at all peculiar to this sub-class, nor even to the vegetable kingdom. Animals, as well as

plants, commonly multiply by simple fission, and amongst the true infusoria, or animalcules, the operation is so rapid that, in some genera (as, for example, the vorticellæ), one may witness within an hour the complete bisection of a single vigorous creature into two lively counterparts. The process in the plant-world is generally much slower, but it passes through essentially the same steps and may be traced with equal clearness and certainty. In fact, at their foundation all modes of reproduction are but forms of fission,—the division of one into two or more,—and the ultimate nature of the process is not changed by the fact that the resulting two are often so dissimilar in size and other attributes that we feel bound to regard one as the parent and the other as the offspring. In other words, it is none the less fission because it takes the form we call budding.

I have a strong liking for the system which classifies this whole matter under the two heads, continuous gemmation and discontinuous gemmation,—the former covering all cases in which the bud or fruit remains permanently attached to the parent stock, and the latter those cases in which it is set free to shift for itself. Examples of continuous gemmation are found among those non-vascular algæ which are nevertheless multicellular in habit, as well as among those animals whose individuality is wholly subordinated to a commensal mode of existence. Under the first head we have such lowly plants as the net-like hydrodictyon, the thread-like spyrogyra, and the chain-like diatoms; under the second we find all such perplexing creatures as the sponges, corals, and zoöphytes.

Continuous gemmation gives rise to very interesting and complicated relations which involve another insoluble biological puzzle,—as to what constitutes an individual. When one regards the cell-units, with their circumscribed and apparently complete cell-functions, he is disposed to credit them with the real individuality; but when he looks to the mutual interdependence which usually exists between the cells which retain a physical connection with one another, he inclines to expand the idea so as to include all the members of any communal aggregation, if he does not stretch it still further, as some authors do, so as to cover all the products of fission or gemmation within a continuous series, whether remaining united or not. In such cases, however

as those of the filamentous and flabellate diatoms, in which there is no absolutely necessary connection between one cell and another, and where there is no known reason why any single frustule would not go on in the performance of all essential functions if it were entirely separated from its sister cells, we seem to be quite justified in regarding the type as physiologically unicellular, even though the anatomical units are not always physically solitary or free. There is at least no evidence that those diatoms which are found within a *thallus* (as already mentioned) have anything more than a mechanical connection with one another, and vital independence is after all the best test we have of their actual individuality.

For some as yet unexplained reason, multiplication by fission sooner or later results in an exhaustion of the vital powers, which would lead to a rupture of the line of descent if it were not for the introduction at this point of the phenomena of conjugation, which, in some mysterious way, give fresh impetus to the reproductive energy. This new departure is brought about by the merging of two organisms into one and the formation from their combined substance of an enlarged and reinvigorated mother-cell, called a zygospore, which becomes the progenitor of a new family, descending from it by the original process of self-division. But the exact nature and office of the zygospore are enveloped in great uncertainty, which has been deepened rather than elucidated by a good deal of hasty inference which has been put upon record as established fact. Thus, it has been asserted that two zygospores sometimes arise from a single union, and also that conjugation results in the production of a "sporangial frustule," which undergoes in itself a segmentation which ends in the formation of true spores, which are set free by the rupture of the containing envelope and which then establish large numbers of new centres of diatom-life. These and other reputed phases of the reproductive process rest upon observations which are more than doubtful, but even if they shall be at last accepted as true, the entire matter will still be found to be reducible to modes of gemmation, either continuous or discontinuous.

As has been indicated already, the medium through which the vital forces work out their wonderful effects is the internal protoplasmic substance of the diatom, otherwise known as the endo-

chrome. It is this mysterious, active matter which, with a chemistry peculiar to itself, gathers up the soluble silicates from the water in which it lives, and builds them into its enclosing tissue or film to form its beautiful glass-like shell, and it is this same restless and expanding endochrome which, in multiplying itself by binary subdivision, pushes apart the valves of its containing case and, as fast as it thus gains room, constructs in the enlarging chamber new siliceous walls encasing the nascent pair of diatoms into which the growing frustule is divided. Thus it comes about, by imperceptibly fine transitions, that the crystal jewel-case and its delicate, living contents are, at one and the same time, transformed, by the natural magic in which the microscopical world abounds, into duplicate descendants hardly distinguishable from each other and closely resembling in every particular the parent form whose individuality is lost in the new units which have taken its place. This remarkable operation is going on every minute, and in countless centres of vital activity throughout the whole world, and of course it has been going on for numberless ages since the first diatom or its evolutionary progenitor made its appearance in the waters of the earth. There is exceedingly strong probability too that this dividing and subdividing will continue during all time to come; and so, whether we regard the matter retrospectively or in anticipation, we perceive a practically endless chain of diatom-life, through which threads an unbroken line of protoplasmic succession. In the higher orders of living things one generation passes entirely away and the following generation sooner or later becomes the head of the family or race. But amongst the lowest creatures, when one bit of animate jelly becomes two bits of animate jelly, the distinction of generations cannot be preserved and there is a nearly strict continuity and identity throughout the genetic line from beginning to end. In other words, the stream of living matter flows on forever, its component substance never disposed twice in exactly the same manner, yet always essentially the same stream. Some portion of it undergoes chemical transformation from time to time, and the waste is supplied by acquisitions of new material, as the water of a river is evaporated and replenished, but the identity of the stream is, in a sense, never lost. On this conception has been erected an ingenious theory of immortality, in which the ideal

protoplasm figures, not quite accurately, perhaps, as the one material thing which is the same yesterday, to-day, and forever.

I have already said, however, that the ideal protoplasm of the philosophers and the actual protoplasm known to the biologists are two very different matters. The former, you will remember, is a colorless, homogeneous, structureless colloid, like glycerin; but the veritable thing which we are able to get under the microscope is always much less simple in appearance and is generally complicated with other substances. The endochrome of the diatom, for example, is usually spoken of as if it were wholly protoplasm, when in fact it is made up of soft parts and harder parts, transparent spots and nearly opaque spots, liquids, semi-liquids, and solids, together with the green chlorophyll and a brown coloring matter, and, in addition to the vacuoles of which I spoke some time ago, veritable oil drops, which are supposed to correspond with the starch-granules of the higher plants. Under the microscope the endochrome therefore looks like what it really is,—a mixture of numerous substances of various colors and consistencies, with, however, a tendency to greater and greater density towards a certain central spot which has always been an object of great interest to investigators. This area of condensation is known as the *nucleus*. Formerly undue mystery was attached to it, as the supposed shrine of the vital spirit. Here, it was fancied, life had been traced to its ultimate hiding-place. It was believed that there could not be a living unit without its nucleus, and, as the anatomical unit was taken to be a closed vesicle, called a cell, all living creatures were, in the last analysis, reduced to a single cell with its nucleus, or to an aggregate of such cells. But by and by it was found that the enclosing vesicle was no essential part of the ultimate unit,—that in fact it was a product of the enclosed protoplasm and, being later in time, must be subordinate in importance. Then the cell-theory was modified into the protoplasm-theory, and the unit became a lump of protoplasm with its nucleus. But, just as the increasing power of the telescope has compelled a change in our ideas of the nebulæ, by making wha were formerly mere condensations of light resolve themselves into numberless clusters of universes and worlds, with their own centres of force and activity, so the improvement of the microscope has forced upon biologists a recasting of their theories of the

nucleus, by enabling them to resolve it into component parts, and to show that within the so-called nucleus a still deeper nucleus exists, and another within this, and so on down, until the powers of the lens are exhausted and the observer can discern at last only a "germinal spot," or point, where somehow, but he knows not how, vital energy emerges or at least manifests itself.

Further than all this, it has been discovered that numerous organisms exist, in which it is impossible to make out anything at all corresponding to this specialized region; and so the sweeping generalizations which were not long ago accepted, as to the absolute necessity of a nucleus to every living unit, have been completely discredited. Still, a great deal of attention is bestowed upon it in such organisms as do possess it, because in such cases it is evidently the seat of greatest vital activity.

In the diatoms, the first indication we have that self-division is about to take place is the appearance of a sort of uneasiness within the nucleus and the formation of a constriction about the middle of the endochrome. This is at the beginning a mere indentation of the outline, but it gradually deepens and deepens until it finally results in the cleaving of the endochrome in twain. It is one of the most impressive sights a man can witness,—this kneading and moulding of the primal matter of a living organism by an invisible agency, under whose mysterious excitement it trembles and surges and at last rends itself apart. One can hardly hope to come nearer than this to the actual first cause of the organic world.

Having once seen this manifestation of efficient energy within the diatom-shell, we shall not much wonder that the free frustules move from place to place. We may, however, entertain a lively curiosity as to the direct means by which their locomotion is accomplished, although, in the present state of knowledge, I am sorry to say, that curiosity cannot be satisfied.

Amongst the lowest known living things two modes of locomotion prevail. When the organism consists of a wholly soft and mobile material, as is the case with the amœbæ and many vegetable spores, its progression is a form of slow creeping by means of extemporized limbs, or pseudopodia, which are projected as wanted and withdrawn into the general mass after they have once been used. When the creature is of a firmer structure, with an

enveloping sack or skin, its movement is that of swimming, accomplished by the use of permanent hair-like filaments, called cilia, or whip-like lashes known as flagella, which act against the water and propel the creature with considerable velocity.

But the motion of the free diatoms is like neither the quick and nervous swimming, effected by cilia or flagella, nor the slow and measured crawling, performed by pseudopodia. It is in fact a somewhat jerky sort of glide. There are, nevertheless, advocates of the existence both of cilia and of pseudopodia as the means of the diatom's propulsion, although no certain glimpse has ever been obtained of either kind of organ.

In the genus *Navicula*, which includes most of the motile forms, a pretty good magnifying power discloses a central spot, or nodule, in the siliceous valve, with a line, or, in some cases, a double or bifurcate line, extending from it in either direction to the narrowed ends, as the frustule lies with its boat-like outline towards us. This median line is believed to be a lapped or rolled seam between two contiguous plates of which the valve is composed. Whether the edges are rolled so tightly as to form a closed joint, or the union is so loose as to leave an open slit, is still a debatable question; but there seems to be no room for doubt that the thickened welt, to which the name *raphe* has been given, has with it a narrow groove of more or less depth. Now, the advocates of the pseudopod theory of locomotion commonly adhere to the belief in an actual cleft, through which the feet are supposed to be protruded from within the diatom; while the believers in the existence of cilia are generally disposed to accept either a closed or an open furrow as the seat of these oar-like appendages. Since the diatom is really a bivalve, you may begin to wonder why the workers over this problem have not located the organs of locomotion along the suture, or line of junction, between the two valves. But the objection to doing this is that the edges of the two valves are not actually in contact, but rather overlap, like the sections of a telescope tube, the diameter of one valve being slightly greater than that of the other. This overlapping is quite extensive in the larger forms, and gives rise to the appearance of a broad band or hoop encircling the frustule.

Unless, therefore, the raphe is accompanied by an open slit, the diatom is a tightly closed box with its living substance shut

up within. When binary subdivision takes place, the bottom and the top of the box slide apart, while a new top is built on to the old bottom and a new bottom on to the old top;—all inside of the telescopic tubes just mentioned, which are simultaneously extended and duplicated by depositions of new siliceous material upon the surface of the enclosed vegetating protoplasm. When the new frustules are completely formed they are set free by the slipping apart of the telescopic tubes, which, in the case of the free diatoms, usually fall away as genuine hoops, but in the case of the filamentous forms more generally remain adherent to the new frustules.

I have spoken of the living substance of the diatom as being sealed up within its glass case; but this view of the matter must be taken with some qualification, since the vital functions could not proceed unless there were communication of some kind between the endochrome and its environment. The silex-coated cell needs to be pervious to liquids and gases, as much as if it had only a cellulose wall, like most other plant-cells. From what we know of vegetable physiology generally, we do not run much risk in assuming that a constant interchange of elements takes place between the active body within and the world of inert matter without, by means of what is known as osmose.

This presumption has furnished the basis for a third theory of diatom-motion, which assumes that when endosmose occurs at one end of the frustule exosmose occurs at the other, and that the diatom is accordingly partly drawn and partly pushed along by this sucking and ejecting operation. It is held that the flow is not always in the same direction through the cell, but is subject to alternation, which some observers believe to be at regular intervals under all ordinary circumstances, though it is assumed to be more likely that the direction, duration, and change of the current depend upon some subtle and inconstant cause, like the action of light or of heat.

It is well known that all protoplasmic bodies are delicately sensitive to external stimuli, of which light is one of the most active and potent. The researches of Strasburger into "the action of light and of heat upon swarmspores" have shown that it is the actinic end of the spectrum which exerts the irritating influence which results in their migration, while the green, yellow

and red rays are inactive or neutral. Like the movement of swarmspores, as well as that of desmids, the locomotion of diatoms is influenced by light. If water containing these organisms is shaken up and poured out into a shallow vessel and set in a bright place, the diatoms will quickly separate themselves from the dirt and débris with which they have become mixed, and, rising to the surface, will gather together on the side of the vessel most under the influence of the light. The philosophy of this operation appears to be that the light promotes the chemical action, whatever it may be, within the protoplasmic contents of the frustule, which develops a force that reacts upon the water and results in the propulsion of the diatom in the direction of the light. I cannot myself understand why such a result should be produced if the cause of locomotion were the direct action of pseudopodia or cilia, unless we are to admit a certain degree of purposeful control of those organs towards the definite end of seeking the light,—which calls for an exercise of choice on the part of the diatom, at least equal to the apparent volition involved in the food-seeking movements of unquestioned animalcules. On some such theory as that of chemical or osmotic action promoted by light, however, I can easily imagine a reasonable explanation of the phenomenon not inconsistent with the generally accepted belief in the diatom's essentially vegetable nature.

By adopting this hypothesis, as I understand so high an authority as Prof. H. L. Smith has done, I confess that it seems to me we best get rid of that baffling question as to volition; for if the diatom's movements are merely a species of heliotropism, there is no more room for will or mind in the matter than there is in the case of any of the shrubs which turn their flowers or leaves in a given direction to the sun. Surely the evidence of choice in the action of the diatom is no greater than it is in the wonderful discrimination exercised by the roots, tendrils, and tentacles of higher plants, as shown by the delicate experiments of Charles Darwin and his son. I am aware, however, that it is laid down, as a fundamental axiom of psychology, that the function of selective discrimination is the root-principle of mind. But this train of thought leads to deeper questions than it is proper for me to enter upon at this time. I have endeavored, thus far, to confine myself mainly to those phases

of my subject which come naturally within the province of biology, or which present themselves to the mere observer with the microscope. While it is both easy and agreeable to wander in the paths of speculation, we must now keep to the direct line of tangible investigation, which leads us back to the consideration of our little silex-coated cell and its physical substance and structure.

From what has been said concerning the architecture of the typical frustule, you will have inferred that whenever, by any means, its organic material is destroyed, its two valves will fall apart, and that, if the diatom is in an advanced stage of incomplete subdivision, it will break up into four valves and two hoops. To such constituent parts the microscopist commonly reduces his diatomaceous material, by treatment with acids, for purposes of permanent mounting and preservation. Nature, also, is constantly removing the soft and perishable endochrome from diatoms which have run their life's course, and is steadily depositing their nearly indestructible remains at the bottom of almost every permanent body of water. As diatoms have swarmed in river, lake, and sea for countless ages, at least since the glacial epoch, their flinty shells have come to form beds and strata of very considerable extent in numerous parts of the world. Since the fresh-water, salt-water, and brackish-water deposits are very dissimilar in character, as are also the prevailing forms of different periods, these diatomaceous (or "infusorial") earths supply chapters in the history of our globe which are of very great interest and importance, but which some geologist will need to expound to you.

Amongst the largest and best-known of these deposits are that which underlies the city of Richmond, Virginia, and its vicinity, and the one near Virginia City, Nevada. The "Richmond earth" forms a stratum of from 8 to 30 feet in thickness, lying near the surface and extending throughout the eastern part of Virginia and portions of Maryland. There is some reason to suppose that this extensive deposit is related to if not actually connected with deposits recently discovered, at depths of several hundred feet, at Atlantic City and other points in Eastern New Jersey. The forms prevailing in these deposits are of the kinds peculiar to salt water, and their accumulation, in these immense beds of wide extent and great thickness, is evidence of a long-

continued submergence of the regions in which they are found beneath an arm of the sea.

The Nevada deposit is of very pure fresh-water forms, and was laid down in one of two great intra-glacial lakes, which geologists tell us were nearly as large as Lake Superior, one of which filled the Utah and the other the Nevada basin. The Nevada deposit has been worked commercially for a number of years, as the source of the polishing-powder which goes by the trade name of "Electro-Silicon." This and other diatomaceous earths are also employed to some extent, I believe, to form an absorbent base for certain high explosives. Indeed, very many of these earths are valuable articles of commerce, and I understand that at least one business house in this city makes a specialty of the trade in them. They furnish silica in a finely-divided form, suitable, amongst other things, for the manufacture of the silicate of soda or of potash, —otherwise known as "soluble glass,"—which is an ingredient in the glazing of pottery, in artificial stones, and in certain cements and paints.

But it is not because of their practical usefulness that diatomaceous earths are of interest to us. Our attention is now fixed upon diatoms merely as objects of scientific investigation and study. Such they have been, in varying measure, in both their recent and their fossil forms, from almost the dawn of microscopical science, a little over two centuries ago,—observers having been attracted to them mainly by the beauty and variety of their shapes, of which you will presently be enabled to judge for yourselves, by means of the photographs which will be thrown upon the screen.

Under the microscopical powers of early days the valves of all but the very largest species appeared as simple in structure as if made of perfectly plain transparent glass. Some of the coarsest, particularly the discoidal forms, displayed upon their surface a dotting or embossing, with occasionally a rayed or more complicated pattern. A few of the angular forms presented a structure of coarse hexagonal netting, while some of the elongated and boat-shaped kinds were seen to be possessed of stout ribs running at right angles to the median line, or keel. At a later period, not only was the mere magnifying power of the microscope greatly increased, but, what proved to be of much more importance,

methods of illumination were devised which enabled the observer to throw beams of light of different sorts upon the object at various angles of incidence. By this means it was discovered that lined shadows were cast upon the surface of valves which had previously appeared entirely smooth and clear. It was found that these shadows are caused by shallow furrows running, not only lengthwise of the valve, but also at right angles to the median line or even obliquely to it. For a long time it was regarded as the acme of manipulative skill to display this simple system of striation upon the larger and coarser forms upon which the distance between the lines ranges from the 20,000th to the 50,000th of an inch. By slow degrees the microscopist attained to the ability to show at once two or more systems of lines, producing a cross-hatching with square, lozenge, or hexagonal interspaces, and at about the same time it began to be possible to discern upon some of the smaller specimens a striation having only the 80,000th or the 90,000th of an inch between lines. This was the maximum of attainment about thirty years ago. Since then progress has been slow in this department of microscopy and each small step achieved has caused a disproportionate amount of labor and discussion. But after a while an advance was made to the resolution of lines less than the 100,000th of an inch apart, upon such fine species as *Frustulia saxonica* and *Amphipleura pellucida*, and the methods which rendered this progress possible brought double systems of lines to view on those diatoms which had before shown only one system (like *Surrirella gemma*), and raised to the rank of well-defined dots the interspaces in the previous cross-hatching upon the more robust species, such as *Pleurosigma angulatum*. Then it was that microscopists ventured on the important generalization that the typical form of marking, throughout the whole subclass of diatomaceæ, is a series of dots, oftenest arranged in formal rows, but sometimes scattered irregularly over the shell.

As to the precise nature of these dots, there has always been, and is now, a wide difference of opinion, although I venture to think there is no scientific puzzle to the solution of which more intelligent effort has been devoted or over which a more earnest contention has prevailed. The combatants have arrayed themselves in three armies, defending respectively the theory of

bosses, of pittings, and of perforations. Until very recently the preponderance of opinion has been with the advocates of the existence of hemispherical protuberances from the outer surface of the valve. The valve itself has generally been taken to be a single layer of silex. But of late a good deal of evidence has accumulated to show that it is composed of at least two layers and perhaps three, and the idea is rapidly gaining ground that the dots are perforations of the middle layer, if there are three layers, or of the inner one, if there are only two. The outermost lamina and the innermost also, if the threefold theory holds, are supposed to be exceedingly thin, the main weight of material being in the perforated layer between. In fact, the outer layers are regarded as mere membranes overlying a sieve-like wall, of which the areolæ may be round, square, or hexagonal in form.

This last-named theory accords best of all with our belief in the vegetable nature of the diatoms and what we know to be the requirements of the vegetable cell. The sum and substance of this theory is that the cell-wall is not a solid and impervious mass of silex, as was formerly supposed, but that the arrangement of layers which I have described gives it a semi-punctate structure which, while affording all necessary strength, allows full play to the vegetative processes which, through osmotic action or otherwise, depend upon communication between the enclosed endochrome and the exterior world.

But all this brings us once more face to face with the biological problems with which we began the consideration of this subject this evening. As I predicted at the beginning of this lecture, our latest and most extended knowledge, like our earliest and simplest, ends at the everlasting interrogation-mark. There never can be a finality to human research. Physicists speak with some confidence of an ultimate indivisible unit, the size of which they even undertake to estimate in a rough sort of way; and yet if, in the course of ages to come, the power of the microscope should actually reach that degree of development which was falsely claimed for it a century and a half ago (when Joseph Highmore and others declared that the lenses of that day enabled one to see "the atoms of Epicurus" and "the subtile matter of Des Cartes"), I have no idea that there would be a cessation of microscopical endeavor, or that there would be any

general concurrence in the belief that the final unit of all material things had been reached. You may be sure there would still be a goodly number of men endowed with that high order of inquisitiveness which finds its full satisfaction in merely solving problems, and who would persist in peering and prying, determined to find something beyond the so-called end.

Of this class are the men who have worked away at the diatom-markings, through good report and evil report, encouraged and sustained by an abiding faith in the intrinsic value of pure truth. To one unfamiliar with microscopical science the length of time and amount of labor, on the part of both the worker with and the constructor of lenses, which were required to accomplish the progress in mere technical achievement which I have briefly described, must be a matter of profound surprise and wonder; and even after one has in a measure realized that many years of patient and persistent effort were consumed in getting over the ground between merely seeing plain lines the 50,000th of an inch apart, and breaking those lines up into visible dots having a distance of the 50,000th of an inch between their centres (which is in most cases the equivalent of resolving lines the 100,000th of an inch apart), he may still be unable to appreciate the importance of the accomplishment or to believe that the result could warrant the necessary expenditure of energy. But the pursuit of knowledge for the sole sake of knowledge has been justified over and over again by the discovery that what was sought with entirely disinterested motive and with no utilitarian aim, has proved to be a precious boon and blessing to all mankind. And so the enthusiasts who used to spend their time "fighting objectives," and who braved the jeers of their more practical brethren, have now the satisfaction of knowing that their exacting demands for improved apparatus with which to resolve more and more difficult tests, have been the incentive under which the opticians have produced lenses of wider and wider angle of aperture, with better and better correction of aberrations. The result has been, first, the working out of the very ingenious homogeneous immersion principle and, more lately, of the wonderfully delicate apochromatic combination, in the application of which to the microscope objective a revolutionary theory in optics has been developed, while, at the same

time, the whole science of bacteriology has been rendered practicable, and the mysteries of disease and death have been disclosed to seers like Pasteur and Koch, for the benefit of us and all coming generations.

ON THE EFFECTS OF HYDROXYLAMINE AS A PARALYZING AGENT FOR CONTRACTILE ELEMENTS.[1]

BY E. A. SCHULTZE.

(*Read November 20th*, 1891.)

The preparation for microscopical study of animals having exceedingly contractile elements, and which when killed are, in consequence of the irritating properties of the embedding material, often rendered unrecognizable, may be added to the more difficult methods employed in the art of preservation.

Thus, for instance, in preparing slides of infusoria great difficulties are met in fixing Stentor, Vorticella, Spirostoma, etc., and it is always a matter of chance if one or the other of these animals is secured in a partially extended state by the methods in use up to the present time. Similar difficulties are encountered in fixing Hydrozoa, and especially Actinozoa, Planariæ, Rotifera, and all kinds of mollusca, etc., all of which shrink more or less under the influence of the preservative reagents.

In order to overcome as far as possible these difficulties which occur in course of scientific investigation, and especially in slides prepared for school use, two methods have been adopted which in some few cases have proved successful.

At first the attempt was made to instantly kill metabolic animals in a distended state by means of extremely effective agents, such as Lang's solution, which may be successfully used on Planariæ, osmic acid for many Protozoa, corrosive sublimate, and other boiling reagents. But as the effects produced by these methods, despite their excellent preserving qualities, are generally restricted, the trial was made to paralyze the contractile elements by means

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[1] Abstract and translation from an article by Dr. Bruno Hofer in Zeitschrift für wissenschaftliche Mikroskopie, vii. 318 (1890).

of proper poisons, and then to fix the paralyzed animal. Satisfactory results were thus obtained by the use of chloral and different alkaloids, such as cocaine, antipyrine, antifebrine, etc., with or without subsequent poisoning. These paralyzing methods, which, moreover, are not always effective, have the great disadvantage that, through the action of the paralyzing reagents, which are in most cases specific protoplasmic poisons, a simultaneous swelling of the protoplasm occurs, so that, although the topographical conditions are retained, the histological details are in many cases destroyed.

On that account a method is to be desired which will permit metabolic animal forms to be fixed in a distended state, and at the same time sufficiently insure their preservation, especially in the case of those animals which have hitherto resisted all attempts towards preservation. These results are to be obtained, as I have subsequently shown in a series of experiments, with the aid of hydroxylamine, *i.e.*, with its hydrochlorate or sulphate, by means of which the smooth and striated muscles of many Metazoa are paralyzed to such an extent that a subsequent contraction, while fixing them afterward, is hardly perceptible. A sufficient paralysis is also obtained before a swelling of the protoplasm in the cells of the paralyzed object is noticeable.

A series of careful examinations with abundant material will have to be made to determine to what extent hydroxylamine poisoning may be used. The favorable results that I have obtained with Protozoa, Hydrozoa, Actinozoa, Planariæ, Annelida, Rotifera, Mollusca, etc., lead me to believe that hydroxylamine, as a paralyzing agent, will be more generally used.

The following directions may be recommended in using hydroxylamine :

One per cent of the crystals of the commercial hydrochlorate, which are usually impure, is dissolved in fresh water, and enough carbonate of soda added to render the solution neutral. This solution may be kept on hand in large quantities for use at any time. Distilled water must not be used in preparing it, but in the case of marine forms salt water must necessarily take the place of fresh. It is not advisable to eliminate the hydroxylamine from the hydrochlorate solution by adding an excess of carbonate of soda, as the liquid then obtained would over-excite the animal.

After the animals have been paralyzed in the neutral hydrochlorate solution they are immediately covered with the fixing medium and thereby killed.

The number of fixing reagents that may be used is of course limited. For, hydroxylamine being a powerful reducing medium, all easily reducible agents, such as osmic acid, corrosive sublimate, chloride of gold, of platinum, etc., cannot be directly applied. The hydroxylamine must first be worked out with water. Alcohol, acetic and picric acids, and mixtures of these two acids may be directly applied, and with these a good histological slide may always be obtained.

The strength of the solution depends, of course, on the nature of the animal to be mounted. In the case of a few special objects I find the following directions may be respectively used :

1. *Stentor cæruleus.*—Place the Stentors for ten or fifteen minutes in a 0.25-per-cent solution of the hydrochlorate. A large proportion of the animals soon stretch themselves out and remain in the semi-distended condition which free-swimming Stentors usually show. No subsequent contraction occurs. The paralyzing effect of the hydroxylamine is soon apparent, but is, however, not sufficiently complete to commence the fixing process. The paralysis must first extend to the cilia. After some ten minutes the cilia of the peristome move irregularly and slower, and finally cease moving altogether. This change must be carefully noted, for at this step the Stentors are suddenly flooded with a concentrated solution of picric acid mixed with a 5-per-cent solution of acetic acid. The majority of the Stentors are now pear-shaped; a few are distended their full length ; while others have the same round shape that Stentors assume when fixed before having been previously paralyzed. The peristome cilia of each individual remain extended and are not drawn back. Sometimes the smaller forms are killed inside of ten minutes through the action of the hydroxylamine, the protoplasm swells, and the animals are entirely deformed. It is consequently always necessary to observe the action of the hydroxylamine from time to time through the microscope, and to add the picric acid before the protoplasm in the larger forms appears to swell; for if left too long the hydroxylamine will act as a poison on the protoplasm, as has been shown by Loew in his experiments with vegetable protoplasm. If the action be stopped, how-

ever, at the right moment, the histological details will be preserved. The Stentors may then be washed in alcohol of 70 per cent, and stained in a rose-red solution of borax-carmine in hydrochloric alcohol of 70 per cent. A satisfactory stain will be obtained in about one hour's time. The Stentors being likely to contract if transferred from absolute alcohol directly to oil of cloves, it is advisable to place them in oil of cloves strongly diluted with absolute alcohol, which latter is allowed to evaporate. This proceeding must be followed when mounting the specimens in Canada balsam. If all the above-mentioned details are adhered to, better slides will be obtained than have been produced by any other method.

2. *Spirostomum teres.*—These extraordinarily sensitive infusorians may be treated in the same manner.

3. *Carchesium polypinum.*—The difficulty in preparing *Carchesium* and many other Vorticellidæ lies in the fact that the muscles of the peduncles strongly contract when brought in contact with the preserving liquid, in consequence of which the individuals of a colony are drawn together and the natural bell-shaped form becomes rounded. To overcome this place the *Carchesia* in a 0.2-per-cent solution of hydrochloric hydroxylamine. The peduncles cease their periodic contractions after one or two minutes, and remain distended. After about five minutes the cilia move more slowly, and ten minutes later the individuals are ready to be killed, like the Stentors, by means of picric-acetic acid.

4. *Hydra grisea.*—Although this object is a comparatively easy one to prepare with any good paralyzing agent, I wished to try the hydroxylamine-poisoning process, in order to study the effects it would have on all the different muscles. Besides, the effects on *Hydra* of a 0.25-per-cent solution of hydroxylamine chloride are such that not only the body proper remains distended, but the mouth also sometimes remains open.

5. *Dendrocœlum lacteum.*—In spite of the fact that very good results in preparing sections of Planaria may be obtained with the use of Lang's solution, the latter is unfit for mounting whole specimens, because the usually thick and massive animals, which must be pressed for this purpose, cannot become flattened after they have become hard. It is therefore necessary to place the live animal under the cover glass, press it slightly, and then flow in

the preserving liquid. But, on account of the irritation to which the animal is subjected by this method, abnormal contractions usually occur. It is consequently advisable to first paralyze the muscular system with hydroxylamine, then to flatten the animal under the cover glass, and finally kill it with picric-acetic acid. For paralyzing *Dendrocœlum lacteum* ten or fifteen minutes are sufficient, with a 0.5-per-cent solution of hydroxylamine chloride. The moment the animal stops moving is the best time to kill it.

6. *Hirudo medicinalis.*—To produce good sections of leeches the body must show no contraction after being killed. Chloroform as a paralyzing agent cannot be recommended, as, on account of excessive irritation, the muscles of the leech are often torn. When placed in a 1-per-cent solution of hydroxylamine chloride, the animals stretch themselves out to their full normal length after from one-half to two hours' time, and remain in this state after the fixing medium is added, which may be either alcohol or picric-acetic acid.

7. *Naïs proboscidea.*—*Naïs* has a tendency, when placed in the preserving fluid, to roll itself up sideways and perceptibly shorten its segments. A side view of the body is of course advantageous for the study of the nervous system, but the segmental organs are not visible in this position, as they are covered by the intestines. In order to properly see them the animal must be fixed on its belly or back, when the entire segmental structure is shown. Place the *Naïs* in a 0.1-per-cent solution of hydroxylamine chloride. After twenty or thirty minutes the skin muscles are so lame that the animal hardly moves, and may be fixed on the slide in any position with picric-acetic acid. The specific muscle-paralyzing action of hydroxylamine is especially noticeable in *Naïs proboscidea*, for the animal may remain one hour and a half in the hydroxylamine solution without the ciliary motion in the rectum entirely ceasing, while the skin muscles have become incapable of contraction after about half an hour. Moreover, *Naïs* is able to recover its natural condition if transferred to pure water. The ciliary motion of the rectum again becomes active, and later the skin muscles regain their contractile ability. It is consequently possible, after thoroughly washing the paralyzed animal for about ten minutes, to kill it with other reagents than picric-acetic acid—

for instance with osmic acid, a proceeding to be recommended for studying the segmental canal.

8. *Rotifera.*—The action of hydroxylamine on Rotifers, of which *Noteus quadricornis*, *Squamella bractea*, and *Salpina spinigera* were examined, is also advantageous. After applying a 0.1-per-cent solution the cilia of the discs, as well as the muscles of the tail-like foot, become so lame that both wheel-organ and foot are not drawn in when being fixed with picric-acetic acid.

9. *Mollusca.*—For *Anodonta cygnea* and *Helix pomatia* I recommend a $\frac{1}{2}$ to 1 per cent solution. Both specimens were entirely paralyzed after from ten to twenty hours. The snail had stretched itself out of its house as it usually does while moving in life. The mussel had extended its foot, and the closing muscles of the shell were completely paralyzed. While afterwards fixing in alcohol the animals remained unchanged.

The aforementioned examples are illustrations of the fact that hydroxylamine possesses a paralyzing power in contractile elements, and that it may be used very successfully in mounting.

PROCEEDINGS.

Meeting of October 2d, 1891.

The Vice-President, Mr. J. D. Hyatt, in the chair.

Twenty-five persons present.

Dr. Charles Lehlbach was elected a resident member.

The Recording Secretary read a communication from the Scientific Alliance of New York requesting the Society to unite in arranging a mutual programme.

On motion it was resolved that the matter be referred to the Board of Managers to report at the next meeting.

The Corresponding Secretary announced a donation of diatomaceous material from Mr. K. M. Cunningham, of Mobile, Alabama, accompanied by the following communication dated August 11th, 1891:

"To-day I mailed to your address a specimen of a new diatomaceous material find, recently brought to light by myself. This material is sufficiently cleaned to mount directly. It is from the west bank of the Mobile River, and is a tidal marsh mud taken from three to five feet below the surface, and has probably not been seen heretofore by diatom admirers. Four or five forms occur in great abundance—*Campylodiscus*, *Actinocyclus*, *Terpsinoe*, with a sprinkling of others.

"The material will make elegant balsam or dry mounts for condensed surface illumination for binocular. It is a cleaning by Dr. Geo. H. Taylor, of Mobile, and is of unusual interest before acid treatment, as it shows a fair mixture of a wide variety of rhizopods, sponge spicules and diatoms, not to mention a great variety of transparent plant tissues of great diversity of cellular structure, with scales of mica, which polarize very prettily."

Mr. Hyatt announced the finding of marine forms of diatoms in the filter beds of the city water works of Poughkeepsie, New York.

Dr. E. G. Love addressed the Society on "The History and Development of the Microscope up to the time of Achromatism." This address was a most interesting and able explication of the subject, and was beautifully illustrated by the projection of fifty lantern slides of diagrams, antique instruments and accessories.

Meeting of October 16th, 1891.

The Vice-President, Mr. J. D. Hyatt, in the chair.

Twenty-eight persons present.

The Corresponding Secretary announced the donation to the Society of seventy-five slides of diatoms by Mr. Henry C. Bennett, prepared by him and accompanied by the following communication:

"I prepared the slides from cleaned material obtained from abroad, and they comprise deposits from districts that have received much attention from diatomists, and which have been described in scientific publications. The cleaned diatomaceous material I obtained from M. J. Tempère, 168 Rue St. Antoine, Paris, France, who at intervals of about three months issues a series of twelve tubes of cleaned diatoms in liquid, each tube holding about one-half of a drachm."

OBJECTS EXHIBITED.

1–4. Four new forms of aquatic animal life from the Morris and Essex Canal, N. J.: by Stephen Helm.

5. *Bacillaria paradoxa*, living, from the Morris and Essex Canal: by James Walker.

6. The Worker Ant, *Myrmica scabrinodis* Nyl.: by J. L. Zabriskie.

7. Sting of Wasp, with air in the longitudinal canal of one lance, showing branches of the canal to the barbs: by J. D. Mallonee.

Meeting of November 6th, 1891.

The Vice-President, Mr. J. D. Hyatt, in the chair.

Thirty-three persons present.

Dr. J. A. Gottlieb was elected a resident member.

The following persons were appointed by the chair Committee on Annual Reception: Anthony Woodward, Dr. Edward G. Love, and Charles S. Shultz.

OBJECTS EXHIBITED.

1. *Cordylophora lacustris:* by H. Calef.

2. Transverse sections of Antennæ of House-fly, *Musca*

domestica, showing grooves, horny discs, and fine hairs : by L. Riederer.

3. Sagittal sections of head of Stable-fly, *Stomoxys calcitrans:* by L. Riederer.

4. *Trichina spiralis* in human muscle: by J. A. Gottlieb.

5. One of the new forms of aquatic life exhibited at the last meeting: by Stephen Helm.

6. Section of leaf of Oleander showing stomata: by F. W. Leggett.

7. Section of leaf of Rubber Plant showing stomata: by F. W. Leggett.

8. Portion of stem of Sleepy Catch-fly, *Silene antirrhina* L., with captive insect: by J. L. Zabriskie.

9. Leaf-blade of Long-leaved Sun-dew, *Drosera longifolia* L., with captive insect: by J. L. Zabriskie.

Dr. Gottlieb gave a very interesting account of the nature and action of *Trichina*, and stated concerning the exhibit that it was taken from the biceps muscle at the autopsy of an Italian who entered Bellevue Hospital under the Doctor's care in the spring of 1890, and who died three weeks after, suffering from trichinosis.

Mr. Riederer explained his exhibits, using in illustration excellent colored drawings of his own preparation.

Mr. Zabriskie exhibited in connection with his slides herbarium specimens of *Silene antirrhina* L., *Drosera rotundifolia* L., *D. longifolia* L., and *D. filiformis* Raf.

Mr. Hyatt stated that the glandular hairs of the leaf of *Drosera* will not move on contact with inorganic matter, but that they will contract upon a minute piece of fresh meat in the space of twenty seconds; and further, that in his experience the insects most abundantly captured by *Drosera* are ants.

Dr. N. L. Britton gave an interesting description of a large insectivorous plant, of the genus *Roridula*, living specimens of which he had seen at the Royal Gardens at Edinburgh. The plant is a native of Tasmania. It is a branching bush, with filiform leaves, more slender than those of *Drosera*, and, like the latter, furnished with glandular hairs with which it captures flies.

Meeting of November 20th, 1891.

The Vice-President, Mr. J. D. Hyatt, in the chair.

Forty persons present.

Mr. M. A. Gottlieb was elected a resident member.

The Vice-President reported the decision of the Board of Managers, that it is desirable that the programme of the Society be published in the Bulletin of the Scientific Alliance.

On motion it was resolved that the report be adopted, and that the necessary expense be met from the funds of the Society.

On motion it was resolved that the Society hold an Annual Reception.

The chair appointed the following as Committee on Nomination of Officers: Walter H. Mead, William G. De Witt, and F. W. Devoe.

The Corresponding Secretary announced the donation to the Society, by Mr. K. M. Cunningham, of Mobile, Alabama, of our prepared slides of rhizopods and two vials of material, accompanied by the following communication dated November 14th, 1891:

"The preparations are the outcome of my most recent find of a diatom-bearing material on the eastern edge of a marsh bordering the Mobile River. The vegetable growth, mostly marsh grasses, rests upon a stratum of a very soft, oozy mud, through which a pole may be readily pushed for a depth of six feet. When withdrawn, the soft mud is scraped off and subjected to the usual treatment for the removal and concentration of diatoms.

"This mud proved to be of unusual richness in variety of micro-organic remains, as may be attested by an examination of the slides prepared from the same. Associated together may be found marine and fresh-water species of diatoms, several interesting varieties of sponge spicules, very numerous tests or carapaces of fresh-water rhizopods, and several species of marine foraminifera. Also there may be seen varieties of pollen grains or spore capsules, many plates of mica, and of less interest the tissues of plants of a partially siliceous nature—*Phytolitharia* (Ehrenberg).

"I have prepared, in a probably unusual manner, a set of four

slides to illustrate some of the features connected with this special deposit. On two slides I show selected rhizopods, to be viewed strictly by polarized light; and two slides of deposit strewn so as to show the various associated micro-organisms by polarized light. These slides have no cover glasses, but are covered by a thin film of mica, with the object of intensifying the brilliancy of the prismatic effects. Under this arrangement we are provided with a kaleidoscopic effect of color, produced by the polarized light when the polarizing prism is revolved.

"I have also sent two vials, one containing the rhizopod, foraminifera, and mica material, the other containing the marine and fresh-water diatoms, concentrated from the mud already alluded to. The diatoms are a water-washed concentration by Dr. Geo. H. Taylor, of Mobile, without use of acids. He is now engaged on the reduction of a large bucketful of the deposit to the same state as that shown by the slide of diatoms prepared from the material in the vial sent herewith. The diatoms indicate an aggregation of about fifty marine and fresh-water species—*Actinocyclus Ehrenbergii*, *Campylodiscus crebrosus*, *Nitzschia circumsuta*, and *Terpsinoe musica*. Another interesting feature is that *Triceratium favus* is absolutely absent, and that *Cymatopleura elliptica* and a pretty *Acanthes* are seen in every slide of the material, while they are almost unknown as occurring in all previous gatherings tributary to Mobile until this locality was casually met."

OBJECTS EXHIBITED.

1. Vanadamite from Arizona: by E. C. Bolles.

2. Percylite from Arizona, together with a large series of minerals in minute paper boxes : by E. C. Bolles.

3. Rhizopods from marsh mud, Mobile River, Alabama, prepared and donated by K. M. Cunningham: by J. L. Zabriskie.

4. A slug-like form of aquatic life: by Stephen Helm.

5. An undescribed form of aquatic life, formerly exhibited as No. 4: by Stephen Helm.

6. An undescribed form of aquatic life resembling *Cordylophora lacustris:* by Stephen Helm.

7. *Hydra viridis:* by Stephen Helm.

8. Young Hydro-medusæ, living: by L. Riederer.

9. Poison from stems of grapes: by L. RIEDERER.

10. Transverse section of leaf of Oleander with stomata: by E. G. LOVE.

11. Section of agate: by J. D. HYATT.

Mr. E. A. Schultze read a translation from *Zeitschrift für wissenschaftliche Mikroskopie*, entitled "On the Effects of Hydroxylamine as a Paralyzing Agent for Contractile Elements." This translation is published in full in this number of the JOURNAL, p. 28.

Rev. Dr. Bolles explained at length the advantages of the minute square paper boxes containing the mineralogical specimens exhibited by him. A short section of a small cylinder of wood is glued in the bottom of each box; a disc of black cardboard is glued on top of the wood, and the specimen is attached to the black disc.

This was followed by a discussion on the sweating of cells containing dry mounts, and especially on the disadvantages of wax cells, which discussion was participated in by Messrs. Cox, Bolles, Hyatt, Leggett, and Zabriskie.

Dr. E. G. Love stated concerning his exhibit that the peculiar appearance of the stomata of the Oleander was due to the fact that the stomata are each seated at the bottom of a little depression in the surface of the leaf, the depressions being lined with minute hairs. Dr. Carpenter mentions this in his work on the microscope, and it probably occurs in only a few genera of plants.

Mr. Hyatt said of his beautiful section of agate that it was composed of aggregated clusters of minute crystals of quartz, showing hexagonal structure of the crystals.

PUBLICATIONS RECEIVED.

The Microscope: Vol. XI., Nos. 8—11 (August—November, 1891).

American Monthly Microscopical Journal: Vol. XII., Nos. 10, 11 (October, November, 1891).

Anthony's Photographic Bulletin: Vol. XXII., Nos. 19—23 (October 10—December 12, 1891).

Botanical Gazette: Vol. XVI., Nos. 11, 12 (November, December, 1891).

Bulletin of the Torrey Botanical Club: Vol. XVIII., Nos. 10—12 (October—December, 1891).

Insect Life: Vol. IV., Nos. 1—4 (October, November, 1891).

Psyche: Vol. VI., Nos. 187, 188 (November, December, 1891).

West American Scientist: Vol. VII., No. 63 (October, 1891).

Natural Science Association of Staten Island, Proceedings: Meetings of October 10, November 14, 1891.

San Francisco Microscopical Society, Proceedings: Meetings of October 7—November 18, 1891.

Journal of the Elisha Mitchell Scientific Society: Part 1, 1891.

Journal of the New Jersey Natural History Society: Vol. II., No. 2 (January, 1891).

Kansas City Scientist: Vol. V., No. 10 (October, 1891).

Bulletin of Michigan Agricultural Experiment Station: Nos. 75—77 (July—November, 1891).

Bulletin of Cornell University Agricultural Experiment Station: No. 32 (October, 1891).

The Microscope and Histology, Part 1: From the author, Dr. S. H. Gage (1891).

The Eleventh Census, An Address: From the author, Hon. Robert P. Porter (October, 1891).

Journal of the Royal Microscopical Society: Part 5, 1891.

International Journal of Microscopy and Natural Science: Vol. I., Nos. 10—12 (October—December, 1891).

Grevillea: No. 94 (December, 1891).

The Naturalist: Nos. 195, 196 (October, November, 1891).

Transactions of the Canadian Institute: Vol. II., Part 1 (October, 1891).

The Ottawa Naturalist: Vol. V., Nos. 6, 7 (October, November, 1891).

The Victorian Naturalist: Vol. VIII., Nos. 5, 6 (September, October, 1891).

Brooklyn Medical Journal: Vol. V., Nos. 11, 12 (November, December, 1891).

Indiana Medical Journal: Vol. X., Nos. 4—6 (October—December, 1891).

Hahnemannian Monthly: Vol. XXVI., Nos. 10—12 (October—December, 1891).

The Satellite: Vol. V., Nos. 2, 3 (October, November, 1891).

Electrical Engineer: Vol. XII., Nos. 179—189 (October 7—December 16, 1891).

American Lancet: Vol. XV., Nos. 11, 12 (November, December, 1891).

National Druggist: Vol. XIX., Nos. 8—12 (October 15—December 15, 1891).

Johns Hopkins University Circulars: Vol. XI., Nos. 92—94 (November, December, 1891).

Mining and Scientific Review: Vol. XXVII., Nos. 14—23 (October 8—December 10, 1891).

Bulletin de la Société Belge de Microscopie: Vol. XVII., No. 10 (October, 1891).

Bulletin de la Société Royale de Botanique de Belgique: Vol. XXX., Part 1 (1891). Comptes-Rendus (July 19, 1891).

Wissenschaftlicher Club in Wien: Monatsblätter, Vol. XII., No. 12—Vol. XIII., No. 2 (September—November, 1891). Ausserordentliche Beilage, Vol. XII., No. 12, Vol. XIII., No. 1 (September, November, 1891).

Nuovo Giornale Botanico Italiano: Vol. XXIII., No. 4 (October, 1891).

La Notarisia: Vol. VI., No. 26 (August, 1891).

Jahrbücher des Nassauischen Vereins für Naturkunde: Vol. XLIV. (1891).

Verein für Naturkunde zu Kassel, Bericht: Vol. XXXVI., XXXVII. (1889, 1890).

Jahresbericht der Naturhistorischen Gesellschaft zu Nürnberg (1889).

Naturwissenschaftlicher Verein, Frankfurt (Oder), Helios: Vol. IX., Nos. 4—6 (July—September, 1891). Societatum Litteræ: Vol. V., Nos. 5—8 (May—August, 1891).

Revisio Generum Plantarum, Part I. By Dr. Otto Kuntze. From the author (1891).

Sociedad Cientifica "Antonio Alzate," Memorias: Vol. IV., Nos. 11, 12 (May, June, 1891).

Revue International de Bibliographie Médicale, Beyrouth: Vol. II., Nos. 9—11 (September—November, 1891).

American Metrological Society, Metrical Tables (1891).

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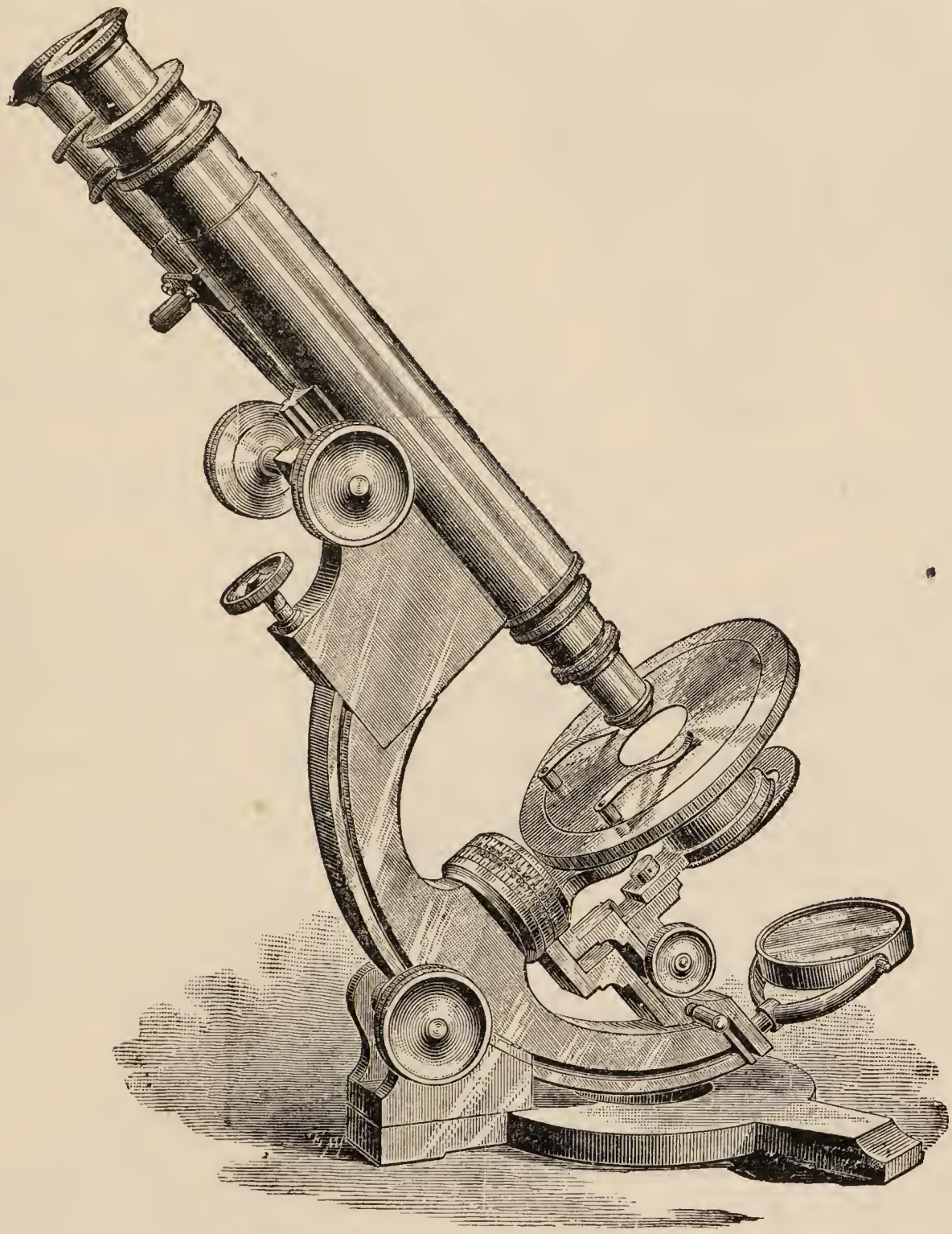

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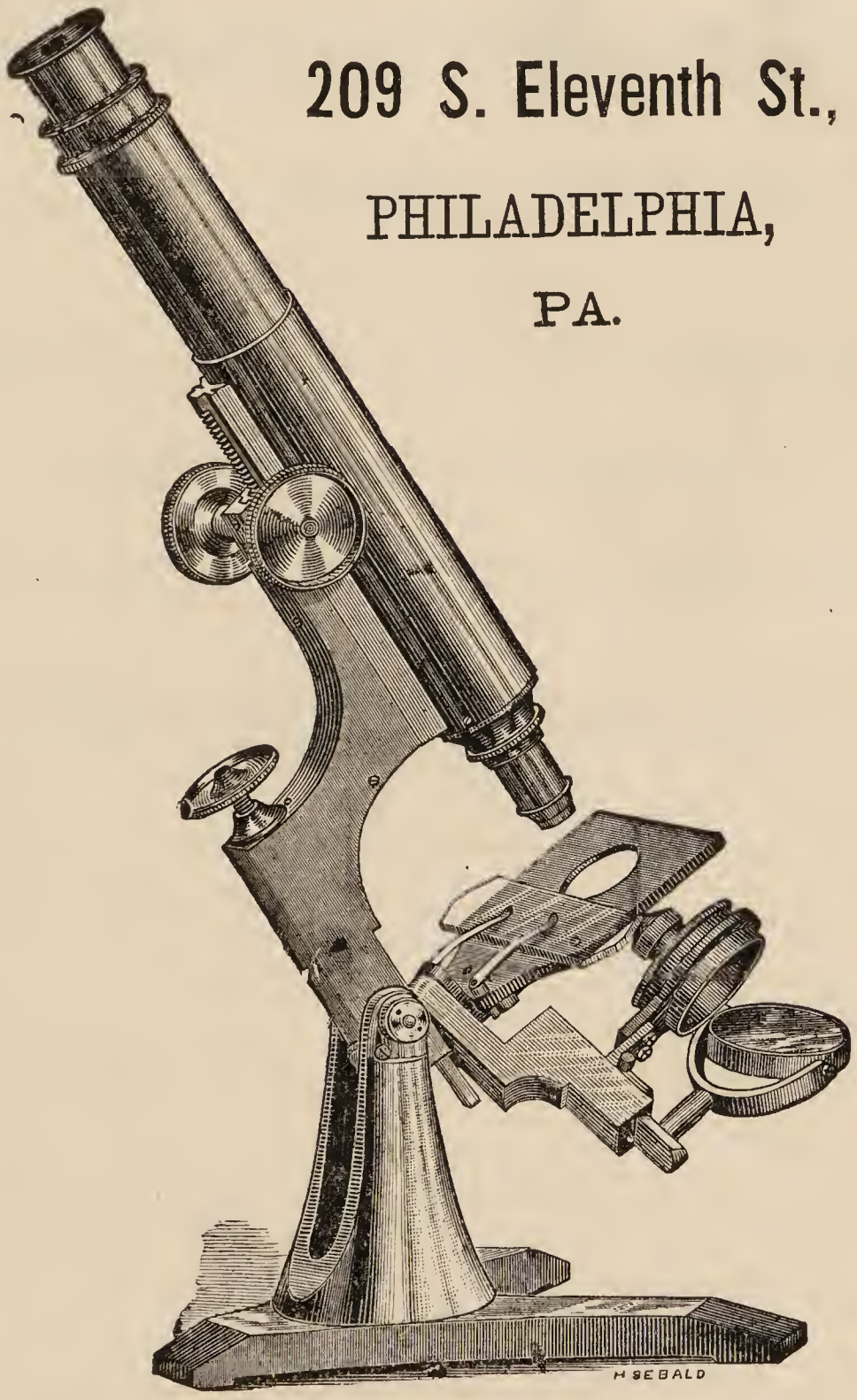

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